APPENDIX F. CRASH ANALYSIS PROCEDURE

An example of the procedure used to analyze the crash data is provided in this appendix. For purposes of illustration, the analysis described below is for total crashes that were reported by the police on 41 experimental sites where speed limits were raised and on their corresponding comparison sites.

The four methods used to estimate safety effects were the multiple before and after analyses with paired comparison ratios, cross-product ratio, EBEST, and before and after analyses using the weighted average logit. The null hypothesis tested was that the observed crashes after treatment, i.e., installation of the new speed limit signs, were equal to the expected crashes after treatment. All statistical analyses were conducted at the 0.05 significance level (α). Rejection of the null hypothesis required a probability or p-value < 0.05.

Procedure

The first step in the analysis was to determine if the crash history for the comparison group was comparable to the crash history for the experimental group during the before period and during the after period. As an excellent discussion of the comparability procedure is provided by Griffin, only a brief summary is included below.[35]

To address the comparability question, the goodness-of-fit test was applied using the likelihood ratio chi-square (G) test as shown below:

$$G = -2 \sum_i \sum_j x_{ij} \ln \frac{\hat{m}_{ij}}{x_{ij}}$$

where:

x_{ij} = observed crash frequency in cell ij, row (i) and column (j)

$$\hat{m}_{ij} = \frac{x_{i+}x_{+j}}{x_{++}}$$

Shown in table 43 are total crashes listed by year for the before and after periods for the raised speed limit experimental and comparison sites. It should be noted that at most sites, the before data covered a 3-yr period and the after data were for a 2-yr period. As crash data were not available for all of the sites for all years, direct comparison of the before and after totals is misleading and inappropriate.

Applying the above formula to the three before periods and to the two after periods shown in table 43 produces the following results:

$$\begin{aligned} G_{before} &= 6.82 \\ G_{After} &= \underline{0.51} \\ G_{comparability} &= 7.33 \end{aligned}$$

Table 43. Crash summary by year for the sites where speed limits were raised.

	Number of Total Crashes	
Year	Experimental	Comparison
Before Period		
B3 - Third	324	280
B2 - Second	346	256
B1 - First	499	325
Treatment Period (New Speed Limits Posted)		
After Period		
Al - First	407	329
A2 - Second	276	205

As a G-value of 7.33 with three degrees of freedom is not statistically significant (G = 7.82, a = 0.05) there is little reason to doubt the comparability of the comparison group. In other words, during the 3-yr before period and, again, during the 2-yr after period, crashes at the comparison and experimental sites changed at a similar rate.

It should be noted, however, that the rate of change in crashes from B1 (the year before the speed limit change) to Al (the year after the change) is less for the experimental sites than it is for the comparison sites (4071499 = 0.82 compared to 3291325 = 1 .01). This suggests that crashes at the experimental sites may have decreased following implementation of the higher posted speed limits.

As crash histories during the multiple before and after periods at the experimental and comparison sites were comparable, the next step in the analysis was to estimate the change in crashes following implementation of the new speed limits. The paired comparison ratios method described by Griffin, and the classical cross-product ratio were used to estimate the safety effects.

In cases where the crash histories at the comparison sites were not comparable with the crash histories at the experimental sites, i.e., the G-value is statistically significant, only a before-and-after analysis was conducted. When the crash histories are not comparable, it is not appropriate to use the comparison sites to estimate safety effects.

The paired comparison ratios method estimates the overall effect of the speed limit changes on crashes using a weighted average log odds ratio based upon the individual log odds ratios of the crash counts at each treatment location. In this study, the comparison ratios included the crash counts, traffic volumes, and crash repotting periods. It was assumed that the crash reporting periods were known without error. It was also assumed that the crash counts and traffic volumes were known with error. Accordingly, the weighting coefficient was calculated using the reciprocals of the before and after crashes, and before and after traffic volumes for the experimental and comparison sites. In addition, a chi-square test of homogeneity was used to determine if the treatment effects were consistent among the locations studied. The test of homogeneity is applied only when statistically significant treatment effects are found.

Shown in table 44 is the application of the method for the sites where speed limits were raised. The data presented in table 44 contain all of the raised speed limit sites and corresponding comparison sites. In a few cases, when two experimental sites were in close proximity and two suitable comparison locations were not available, speed and crash data were collected at one comparison site. In the crash analyses, duplicate comparison sites were not used.

Several of the experimental and comparison sites had zero crashes in either the before and/or after periods. Because the natural logarithm of zero is undefined, a value of 0.5 was substituted for zero so the analysis could proceed. In cases where the experimental site did not have a corresponding comparison site, the comparison ratios and corresponding odds ratios were calculated using only the crash counts, traffic volumes, and time periods for the experimental sites.

Excellent summaries of the paired comparison ratios method with examples are given by Griffin.[36,37] Both Griffin and Pendleton provide good examples of the cross-product ratio.[35,38] The EBEST methodology is not presented in this report as an excellent discussion is provided by Pendleton.[38]

The results of the paired comparison ratios analyses, shown in table 44, indicated that there was no significant difference in total crashes after speed limits were raised at the 41 experimental sites, Z = -1.37. The cross-product or odds ratio method and the EBEST estimate also indicated that there was no significant difference in total crashes. In this report, the safety estimate (in percent), the Z-value, and the level of significance are presented along with the 95 percent confidence limits.

As the reference group size required by EBEST could not be obtained for this analysis, the EBEST estimates are not valid. The EBEST method was employed in this analysis to obtain an indication of regression-to-the-mean bias present in the dataset, because the paired comparison ratios method does not specifically account for regression-to-the-mean bias.

For the crash dataset, the EBEST method indicated that the average shrinkage was 0.10, which suggests little regression-to-the-mean bias. Average shrinkage factors range from 0 (no regression-to-the-mean bias) to 1.0, indicating substantial bias. A factor of 0.10 suggests that the posted speed limit increases made in this study were not conducted primarily at high-crash locations, or perhaps using multiple years of data in the analysis minimized the effect. Due to the low shrinkage factor, it was felt that regression-to-the-mean bias had little effect on the safety estimates obtained.

Table 44. Example of paired comparison ratios method using raised speed limit sites.

Site	Experimental Crashes		Comparison Crashes		Comp. Ratios		Percent							
Number	Before	After	Before	After	C	B*	Change	Z	L	w	wL	$(L-Lt)^2$	$w(L-Lt)^2$	wL^2
AZ02E	4	2	12	7	0.59	2.38	-15.8	-0.17	-0.1721	1.0218	-0.1758	0.0027	0.0028	0.0303
AZ03E	16	5	1	4	1.19	18.99	-73.7	-1.08	-1.3345	0.6606	-0.8816	1.4759	0.9750	1.1765
CA06E	27	13	55	20	0.34	9.07	43.3	0.84	0.3598	5.4829	1.9726	0.2298	1.2601	0.7097
CA07E	87	40	55	20	0.39	34.01	17.6	0.50	0.1623	9.5336	1.5478	0.0795	0.7581	0.2513
CO01E	16	4	12	4	0.27	4.31	-7.2	-0.09	-0.0751	1.5416	-0.1157	0.0020	0.0031	0.0087
CO03E	15	4	12	4	0.35	5.27	-24.0	-0.34	-0.2748	1.5222	-0.4183	0.0241	0.0367	0.1150
CT01E	26	34	171	132	2.18	56.80	-40.1	-1.80	-0.5132	12.2686	-6.2962	0.1549	1.9003	3.2312
CT04E	1	2	0.5	0.5	0.71	0.71	180.6	0.44	1.0317	0.1818	0.1875	1.3255	0.2410	0.1935
DE05E	32	13	12	9	0.78	25.05	-48.1	-1.18	-0.6561	3.2333	-2.1214	0.2878	0.9306	1.3919
IN02E	46	44	28	25	0.88	40.65	8.2	0.23	0.0791	8.2838	0.6551	0.0395	0.3271	0.0518
IN03E	49	59	0.5	0.5	1.05	51.61	14.3	0.07	0.1337	0.2477	0.0331	0.0642	0.0159	0.0044
MD01E	13	8	17	15	0.94	12.24	-34.6	-0.74	-0.4251	3.0421	-1.2931	0.0933	0.2838	0.5496
MDO2E	46	32	17	13	0.80	36.71	-12.8	-0.31	-0.1374	5.2550	-0.7220	0.0003	0.0017	0.0992
MD03E	3	9	32	26	0.86	2.57	249.7	1.74	1.2519	1.9409	2.4298	1.8811	3.6509	3.0418
MD04E	28	21	18	11	0.74	20.61	1.9	0.04	0.0190	4.3120	0.0819	0.0192	0.0829	0.0016
MD05E	78	48	74	55	0.72	55.82	-14.0	-0.59	-0.1509	15.0838	-2.2755	0.0010	0.0147	0.3433
MD06E	6	3	0.5	5	10.29	61.76	-95.1	-1.84	-3.0247	0.3701	-1.1196	8.4393	3.1238	3.3864
MDO7E	4	3	0.5	5	9.31	37.24	-91.9	-1.51	-2.5187	0.3590	-0.9043	5.7555	2.0665	2.2777
MD08E	16	5	1	4	4.17	66.72	-92.5	-2.11	-2.5910	0.6606	-1.7115	6.1078	4.0346	4.4347
MD09E	14	7	4	8	2.30	32.22	-78.3	-1.99	-1.5266	1.6939	-2.5860	1.9795	3.3532	3.9477
MD10E	127	88	13	11	1.01	127.86	-31.2	-0.86	-0.3736	5.3332	-1.9923	0.0645	0.3439	0.7443
MS02E	8	24	6	26	4.24	33.90	-29.2	-0.57	-0.3453	2.6856	-0.9272	0.0509	0.1367	0.3201
TN01E	75	37	18	11	0.59	44.47	-16.8	-0.42	-0.1839	5.3335	-0.9808	0.0041	0.0220	0.1803
TX06E	6	1	0.5	0.5	1.13	6.79	-85.3	-0.84	-1.9153	0.1935	-0.3705	3.2243	0.6238	0.7097
TX07E	31	11	41	16	0.46	14.24	-22.7	-0.56	-0.2581	4.7469	-1.2250	0.0192	0.0910	0.3161
TX08E	42	20	0.5	0.5	0.64	26.89	-25.6	-0.15	-0.2961	0.2455	-0.0727	0.0311	0.0076	0.0215
CO02E	35	7	0.5	0.5	0.38	13.33	-47.5	-0.32	-0.6445	0.2397	-0.1545	0.2755	0.0660	0.0995
CT03E	2	2	0.5	0.5	0.69	1.38	45.3	0.17	0.3738	0.2000	0.0747	0.2435	0.0487	0.0279

Table 44. Example of paired comparison ratios method using raised speed limit sites (continued).

Site Number	Experimental Crashes Before	Experimental Crashes After	Comparison Crashes Before	Comparison Crashes After	Comp. Ratios C	B*	Percent Change	Z	L	w	wL	$(L-Lt)^2$	$w(L-Lt)^2$	wL^2
ID03E	4	0.5	3	4	1.37	5.48	-90.9	-1.42	-2.3947	0.3522	-0.8433	5.1759	1.8228	2.0195
ID04E	2	0.5	0.5	0.5	0.35	0.69	-27.6	-0.13	-0.3224	0.1538	-0.0496	0.0411	0.0063	0.0160
ID05E	3	0.5	0.5	0.5	0.40	1.20	-58.2	-0.35	-0.8714	0.1578	-0.1375	0.5652	0.0892	0.1198
ID06E	78	15	69	20	0.28	21.50	-30.2	-0.95	-0.3599	6.9212	-2.4909	0.0577	0.3995	0.8964
ID07E	82	19	69	20	0.25	20.52	-7.4	-0.21	-0.0768	7.7020	-0.5912	0.0018	0.0142	0.0454
ID08E	4	0.5	7	2	0.28	1.12	-55.2	-0.47	-0.8028	0.3451	-0.2770	0.4667	0.1610	0.2224
MA02E	2	1	1	2	2.25	4.49	-77.7	-0.87	-1.5021	0.3328	-0.4999	1.9113	0.6361	0.7509
ME03E	14	7	4	0.5	0.12	1.71	309.7	0.90	1.4103	0.4051	0.5713	2.3407	0.9483	0.8058
MS01E	0.5	2	7	6	0.83	0.42	381.5	0.94	1.5717	0.3558	0.5592	2.8607	1.0178	0.8789
VA02E	9	8	32	10	0.49	4.43	80.7	0.97	0.5917	2.7127	1.6051	0.5060	1.3726	0.9497
CA04E	117	84	62	35	0.50	58.77	42.9	1.39	0.3572	15.2067	5.4322	0.2274	3.4580	1.9405
IN04E	1	1	4	3	0.71	0.71	40.6	0.21	0.3411	0.3858	0.1316	0.2123	0.0819	0.0449
TX01E	0.5	0.5	4	1	0.22	0.11	363.9	0.67	1.5345	0.1903	0.2920	2.7361	0.5207	0.4481
Total	1,170.0	685.5	866.0	538.5		964.72				130.8945	-15.6595		34.9306	36.8040

Comparison Ratios = Ratio of comparison site after crashes to before crashes, and ratio of before and after time periods and ratio of before and after traffic volumes at the comparison and experimental sites.
B* = Experimental site before crashes multiplied by the comparison ratios.
Change = Percent change in experimental site crashes from before to after.
L = Log Odds Ratio = ln(after experimental site crashes divided by the before experimental site crashes multiplied by the comparison ratios).
w = Weighting Coefficient = 1 divided by the reciprocals of the before and after crashes and traffic volumes for the experimental and comparison sites.
Lt = Weighted average log odds ratio = $\Sigma wL \div \Sigma w = -0.1196$
Lse = Standard error of the weighted average Log Odds Ratio = $1 \div \sqrt{\Sigma w} = 0.0874$
Et = Apparent change in crashes at the experimental sites in percent = -11.28
Z = Standard Normal Z-test = Lt/Lse = -1.37
Lower Limit = 95% Lower confidence limit in percent = -25.24
Upper Limit = 95% Upper confidence limit in percent = 5.30

Chi-square summary to assess the homogeneity of treatment effect:

Source	X^2	Degrees of Freedom
Treatment	$Lt^2(\Sigma w)$ = 1.87	1
Homogeneity	$\Sigma w(L-Lt)^2$ = 34.93	40
Total	ΣwL^2 = 36.80	41

When the comparability tests indicated the experimental and comparison sites were not comparable, the before-and-after design employing the weighted average logit was used to estimate the safety effect. The calculations for this procedure were similar to the ones illustrated in table 44; however, the comparison site data were not used in the analysis.

When the treatment effect is significant, the paired comparison ratios method and the before-and-after weighted average logit method permit the analyst to estimate the consistency of the treatment effect across all sites. The question posed is-Were the changes in crashes consistent or similar for all treatment sites? As reflected in table 44, a chi-square test of homogeneity is used to determine the consistency of the treatment effect. In the analyses conducted in this study, the treatment effects were not significant and the chi-square tests were not significant.